Volume 4 JUNE, 1925 Number 6

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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33 West Thirty-ninth Street, New York

American Welding Society

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AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

Volume 4 June, 1925 Number 6

OUR NEW PRESIDENT

Alfred G. Oehler recently elected president of the American Welding Society is an associate editor of the *Railway Age* and editor of the *Railway Electrical Engineer*. He is a graduate of the University of Wisconsin. After leaving school in 1911 he was employed for a period of two years in the test and experimental departments of the General Electric Company. In March, 1913, he entered the services of the Northern Pacific Railroad in the electrical construction department. For two years beginning in 1915 Mr. Oehler was employed by the Wisconsin-Minnesota Light & Power Company as general foreman electrician with headquarters at Eau Claire, Wis., and it was while with this company that he first became interested in fusion welding. In September, 1917, he was made associate editor of the *Railway Age* and *Railway Electrical Engineer* and in September, 1920, he was made editor of the latter. During 1918 he served as ensign, United States Naval Reserve Force. He became a member of the American Welding Society in April, 1919, a month after its organization, and has served the society successively as chairman, meetings and paper committee and chairman, metropolitan section, and as chairman, meetings and paper committee of the national body. He is also a member of the American Institute of Electrical Engineers and the Association of Railway Electrical Engineers.

ALFRED G. OEHLER

AMERICAN WELDING SOCIETY

FINANCIAL STATEMENT

REPORT OF AUDITOR

Wm. J. Struss & Co., Certified Public Accountants, 130 William Street, New York

April 3, 1925.

American Welding Society,
29 West 39th Street, New York City.

Dear Sirs:

We have examined the Cash for the twelve months ended March 31, 1925.

Attached hereto is a statement of Receipts and Disbursements for the year ended March 31, 1925.

We find that these records are verified by the reports of the Bankers Trust Company and that the Cheques for disbursements are as indicated on the Cash records.

Yours very truly,
(Signed) WM. J. STRUSS & CO.,
Certified Public Accountants.

STATEMENT OF RECEIPTS AND DISBURSEMENTS OF THE YEAR ENDED March 31, 1925

Receipts

Dues	$12,389.63	
Journal Advertising	9,594.76	
Journal Subscriptions	444.08	
Bound Volumes	177.50	
Bulletins	231.02	
Reprints	504.00	
Refund on Cuts	252.99	
Pressure Vessel Reports	86.44	
Administration Expenses A. B. of W.	600.00	
Committee Refunds, Welded Rail Joint	243.47	
Society Emblems	55.00	
Welding Encyclopedias	20.00	
Annual and Fall Dinners	502.00	
Miscellaneous	85.11	
Section Bookkeeping	23.25	
Bank Interest	99.99	
Total Receipts		$25,309.24
Balance April 1, 1924		3,866.32
		$29,175.56

Disbursements

Salaries	$5,250.00	
Editorial Service	1,800.00	
Printing Journal	4,314.10	
Binding Journal	127.98	
Bulletins	304.00	
Reprints	313.10	
Rent	1,152.00	
Telephone and Telegraph	277.72	
Printing (Promotion)	287.44	
Stationery and Printing	582.01	
Postage, etc.	644.12	
Equipment	333.13	
Pins	75.00	
Welding Encyclopedias	16.00	
Annual and Fall Meetings	493.57	
Annual and Fall Dinners	460.78	
New York Section	440.69	
Administration Expenses A. B. of W.	1,000.00	
Miscellaneous	388.50	
Refunds	17.01	
Printing Index	37.50	
Cuts	184.97	
Printing Directory	292.22	
Section Refunds	3,532.50	
Total Disbursements		$22,324.25
Balance March 31, 1925		6,851.31
		$29,175.56

ESTIMATED BUDGET—Year 1925-26

INCOME		EXPENSES	
Advertising contracts (signed)	$8,112.00	Salaries	$5,580.00
Advertising contracts (not yet signed but which in all probability will be signed)	1,176.00	Editorial services	1,800.00
Journal subscriptions	500.00	Printing Journals	4,800.00
Journal bound volumes	250.00	Binding Journals and printing index	175.00
Bulletins	200.00	Printing directory	350.00
Membership dues	13,405.00*	Room rental	1,152.00
		Printing and stationery	1,000.00
		Telegraph and telephone	300.00
		Postage	600.00
		Meetings	500.00
		Equipment	200.00
		Miscellaneous	350.00
		Traveling expenses	500.00
		Admin. exp. of Bureau	900.00
		Promotion — pamphlets, membership letterheads, etc.	500.00
		Section refund (N. Y. Sect. excluded)	4,102.00
		New York Section exp.	500.00
	$23,643.00		$23,309.00

*This figure is based on dues from present members. $2,290 of this is in delinquent dues, some of which will probably be not collected but will be replaced by new members.

UNFIRED PRESSURE VESSELS

Elsewhere in this Journal there is reproduced that portion of the A. S. M. E. Boiler Construction Code which pertains to the rules for the construction of unfired pressure vessels by welding. Members of the Society and others interested are urged to study these extracts carefully. If you feel that there is anything contained therein that will work hardship to your business you should notify the Secretary of the American Bureau of Welding, 29 West Thirty-ninth Street, New York, at once.

Many prominent members of the American Welding Society feel that this code is incomplete and unduly restrictive as far as welding is concerned. It does form a basis for further adjustments and the American Bureau of Welding has succeeded in securing the wholehearted cooperation of the Boiler Code Committee of the Mechanical Engineers as well as other interested organizations in bringing about proper modifications.

A letter is to go out to all those interested in this subject inviting the assistance and cooperation of all those concerned. This letter is reproduced herewith.

"About two years ago the American Bureau of Welding sent out a series of circular letters urging the tank manufacturers to cooperate in an investigation to secure scientific data needed by the A. S. M. E. Boiler Code Committee in their formulation of a code for unfired pressure vessels.

"A small number of tank manufacturers responded to these letters and as a result of their cooperation, the American Bureau of Welding was enabled to test some forty tanks to destruction at the Bureau of Standards. The results of these tests were compiled in a bulletin of 156 pages and were used by the Boiler Code Committee in framing their code.

"Unfortunately, this code is still unduly restrictive in the eyes of the welding fraternity and also incomplete in many respects. As an example of its incompleteness, a lap welded seam is not allowed in the code. The Boiler Code Committee pointed out that no tanks were tested with this type of construction.

"In addition to the necessity of testing tanks of the lap welded construction, it will also be necessary to secure additional data for our Pressure Vessel Committee, which is now being appointed, to go over the A. S. M. E. Code and to suggest modificationa. These suggestions in each case must be accompanied by convincing arguments and test data secured by

an authentic unbiased body such as the American Bureau of Welding.

"We have again secured the cooperation of the Bureau of Standards and results will be obtained at a minimum cost to the individual tank manufacturer. As in the previous instance, National Research Council will be called upon to act as treasurer of the funds.

"The American Bureau of Welding in its previous circular letters pointed out the necessity for the wholehearted cooperation of the entire industry. Those who have been intimately in touch with the situation know that the necessity was not overemphasized. We would like at this time an expression of opinion from your management as to whether or not you would be willing to cooperate in the additional investigations proposed by the American Bureau of Welding. A more complete program will be sent you later if you are interested."

It is proposed to call a conference in New York very shortly and we would welcome letters from everyone interested as to whether or not they would like to be present at this conference and whether they would be willing to cooperate in the proposed investigations. Immediate action and expression of opinion is required.

MEMBERSHIP DIRECTORY

Plans for the Membership Directory are well under way. The Membership Committee desires to secure several hundred additional members before publication of the Directory as the August issue of the Journal. The time left is relatively short. There are still a large number of members that have not secured one new member during the past year. It should be considered as an obligation on the part of every member to secure at least one new member every year. Urge your friends to join at once. An extra copy of the old directory giving full information concerning the Society will be mailed to you or the prospective member upon request.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the number Indicated in Each Case and Mailed to Society Headquarters.*

Positions Vacant

V-23. Assistant Executive. Opportunity for real live wire to connect with general repair welding and radiator works in fast growing city in north New Jersey. Established eleven years. To branch out owner needs reliable assistant executive. Capital not essential. Best location and most up-to-date equipment. Man of good personality and some experience can make unusual connection as active partner. Give particulars of past experience, age and monthly income expected.

V-24. Desires services of a young man who is familiar with welding shops in metropolitan district to sell welding rods and accessories on a commission basis with very good prospects for future development.

V-26. Wanted, a good man to sell welding and cutting apparatus.

V-27. Go-Getter wanted. Need a man to go out and get business for my welding repair works in Brooklyn, N. Y. We do electric and oxy-acetylene welding.

V-28. Electric Welders wanted for tank work. Competent welders needed for piece work. $2.90 paid for welding each 500 gallon tank. If you are interested, send in a brief statement of your qualifications.

V-29. Welder wanted. Need man that can operate arc welders and acetylene torches, to sell welding machinery and a full line of shop accessories in the Philadelphia territory. A good opportunity for a man that is looking for a future.

V-30. Salesman. Need man to demonstrate portable arc-welding machine in New York City.

Services Available

A-33. Foreman or welder desires position. Has had about thirteen years all around experience as an oxy-acetylene welder. Recently resigned from Mechanical Division, Dept. of Street Cleaning, City of New York. Was employed with the City for five years on general plant repair, automobile and other rolling equipment. Can weld aluminum, cast iron, etc., and understand preheating.

A-34. Master Welder. Expert welder desires position as assistant master welder for a railroad. Had executive experience before welding. Can make large savings in production as the result of ten years experience in welding.

A-35. Expert welder desires position. Have had 17 years experience as acetylene welder, 11 years as welder on locomotives in New York Central repair shops, 4 years as foreman of the repair of all kinds of welding and cutting in the steel car shops, one year as head repair man on all makes of welding and cutting torches and gages and one year as general welder on all kinds of work. Have also been doing electric welding as well as acetylene for the past year.

A-36. Welding Engineer available. Can plan, estimate and supervise all classes, repair and production welding by either the oxy-acetylene or electric arc processes. Best of references.

WELDED RAIL JOINTS

Extra copies of the Third Progress Report of the Welded Rail Joint Committee, published as the May issue of the Journal, may be obtained by members at 50c. per copy and by non-members at $1.00 per copy.

This report can also be obtained in bulletin form from the American Electric Railway Association, 292 Madison Avenue, New York, at $1.50 per copy.

Extracts from A. S. M. E. Boiler Construction Code Section VIII.

Rules for the Construction of Unfired Pressure Vessels

TO THE BOILER CODE COMMITTEE OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS:

GENTLEMEN:

The object of the code covering the construction of Unfired Pressure Vessels is to provide safe construction for the great variety of pressure containers now manufactured and used for innumerable purposes throughout the country and under an exceedingly wide range of conditions. The efforts to give publicity which have been made in order to obtain as wide a range of opinion as possible, have brought out views which were often times diametrically opposed. In such cases the attempt has been made to frame the rules in accordance with the greater weight of opinion.

It is believed that these rules will not work undue hardship on the manufacturing industries generally, and at the same time will result in the construction of reasonably safe pressure vessels, for it is undoubtedly true that many of the failures which take place are due to the lack of proper restrictions governing material, workmanship, dimensions and supervision.

Rules for joints of the double-welded lap type and for electric induction compression welding are in process of preparation and will be submitted later on for addenda to the Code.

Respectfully submitted:
E. R. FISH, *Chairman*
WM. H. BOEHM
C. E. BRONSON
E. C. FISHER
S. F. JETER
WM. F. KIESEL, JR.
JAMES NEIL
H. V. WILLE.

The Code thus submitted was approved by the Boiler Code Committee and upon its recommendation, by the Council of the Society on January 15, 1925.
C. W. OBERT, *Secretary.*

These rules are not intended to apply (a) to pressure vessels which are subject to Federal inspection and control, (b) to locomotives of all types, (c) to vessels for containing only water under pressure for domestic supply, (d) to vessels forming part of apparatus subject to an operating temperature exceeding 600 deg. fahr.

U-1. The rules in this section apply to Unfired Pressure Vessels over 6 in. in diameter, having a volume of more than 1.5 cu. ft. and carrying a pressure of over 30 lb. per square inch, constructed of material herein specified.

Material

U-12. Plates for any part of a riveted vessel required to resist stress produced by internal pressure, shall be of flange or firebox quality steel conforming with the Specifications for Steel Boiler

Plate given in paragraphs S-5 to S-17 of Section II of the Code, except as provided in paragraph U-13.

U-13. Steel plates for any part of a pressure vessel which is to be constructed with other than riveted joints shall be of the quality specified for the particular kind of joint used.

Construction and Maximum Allowable Working Pressures

U-17. For all pressure vessels the minimum thicknesses of shell plates, heads and dome plates after flanging shall be as follows:

When the Diameter of Shell is		
14 in. and under	Over 14 in. to 24 in.,	Over 24 in. to 36 in.,
1/8 in.	3/16 in.	1/4 in.
Over 36 in. to 54 in.,	Over 54 in. to 72 in.,	Over 72 in.,
5/16 in.	3/8 in.	1/2 in.

except that for riveted construction the minimum thickness shall be 3/16 in.

U-19. The maximum allowable working pressure is the maximum pressure at which a pressure vessel may be operated.

Where the term "maximum allowable working pressure" is used it refers to gage pressure, or the pressure above the atmosphere, in pounds per square inch.

U-20. *For Internal Pressure.* The maximum allowable working pressure on the shell of a pressure vessel shall be determined by the strength of the weakest course, computed from the thickness of the plate, the efficiency of the longitudinal joint, the inside diameter of the course, and the maximum allowable unit working stress.

$$\frac{S \times t \times E}{R} = \text{maximum allowable working pressure, pound per square inch.}$$

where S = maximum allowable unit working stress in pound per square inch.

= 11,000 lb. per square inch for steel plate stamped 55,000 lb. per square inch, 10,000 lb. per square inch for steel plate stamped less than 55,000 lb. per square inch, and 9000 lb. per square inch for material used in seamless shells.

t = minimum thickness of shell plates in weakest course, inches.

E = efficiency of riveted longitudinal joint, per cent.

R = inside radius of the weakest course of the shell, inches, provided the thickness of the shell does not exceed 10 per cent of the radius. If the thickness is over 10 per cent of the radius, the outer radius shall be used.

NOTE: When the safe working pressure for welded or brazed vessels is to be determined, E will be omitted from the formula and the values for S in Pars. U-68, U-82 or U-94 will be substituted for the values given above. For seamless shells, E equals 100 per cent.

Joints

U-22. Pressure vessels may be fabricated by means of fusion or

forge welding, or brazing, provided the rules governing the method adopted and as given in paragraphs U-67 to U-96 are followed.

U-23. Pressure vessels shall not be fabricated by means of fusion welding under the rules given in paragraphs U-67 to U-79, except:

a. Air vessels, when the diameter does not exceed 20 in., the length does not exceed three times the diameter, and the working pressure does not exceed 100 lb. per square inch.

b. Other vessels, under these rules, in which the circumferential joints only may be welded, when the inside diameter does not exceed 48 in., or 72 in. when at least 75 per cent of the load on a flat head is supported by tubes or stays.

Riveted Joints

U-29. *a*. The strength of circumferential joints of pressure vessels, the heads of which are not stayed by tubes or through braces, shall be at least 50 per cent of that required for the longitudinal joints of the same structure.

b. When 50 per cent or more of the load which would act on an unstayed solid head of the same diameter as the shell, is, in consequence of the holding power of the tubes and stays, relieved by the effect of through tubes or stays, the strength of the circumferential joints in the shell shall be at least 35 per cent of that required for the longitudinal joints.

U-32. Butt straps and the ends of shell plates forming the longitudinal joints shall be rolled or formed to the proper curvature by pressure and not by blows.

Dished Heads

U-36. The thickness required in an unstayed dished head when it is a segment of a sphere shall be calculated as follows:

For $P \times L$ equal to or less than $\frac{1}{2}\ S$,

$$\begin{cases} t = \dfrac{3PL}{4S} & \text{for pressure on } \textit{concave side.} \\ t = \dfrac{5PL}{4S} & \text{for pressure on convex side.} \end{cases}$$

For $P \times L$ greater than $\frac{1}{2}\ S$,

$$\begin{cases} t = \dfrac{PL}{2S} + \frac{1}{8} & \text{for pressure on concave side.} \\ t = \dfrac{5PL}{6S} + 0.2 & \text{for pressure on } \textit{convex side.} \end{cases}$$

where t = thickness of plate, in.

P = maximum allowable working pressure, pounds per square inch.
L = radius to which the head is dished, inches.
S = maximum allowable unit working stress of 11,000 lb. per square inch for steel plate stamped 55,000 lb. per square inch, and 10,000 lb. per square inch for steel plate stamped less than 55,000 lb. per square inch.

Where two radii are used, the longer shall be taken as the value of L in the formula.

Where the radius is less than 80 per cent of the diameter of the shell to which the head is attached, the thickness shall be at least that found by the formula by making L equal to 80 per cent of the diameter of the shell.

When a dished head has a manhole opening, the thickness, as determined by these rules shall be increased by not less than $\frac{1}{8}$ in. over that called for by the formulas.

U-37. When dished heads are of less thickness than determined by paragraph U-36, they shall be stayed as flat surfaces, no allowance being made in such staying for the holding power due to the spherical form. If a dished head is formed with a flattened spot or surface for the attachment of a connection or flange, the diameter of the flat spot shall not exceed the value of p as given in the formula in paragraph U-40, or in Table U-3, for the pressure and thickness of head involved.

U-38. The corner radius of an unstayed dished head measured on the concave side of the head shall not be less than three times the plate thickness up to $t = \frac{1}{2}$ in. For thicker plates the corner radius shall not be less than 3 per cent of L and in no case less than $1\frac{1}{2}$ in.

U-39. A manhole opening in a dished head shall be flanged to a depth measured from the outside of not less than three times the required thickness of the head.

Manholes and Handholes

U-53. All vessels for use with compressed air, 16 in. in diameter, or over, and not exceeding 36 in. in diameter, shall have a handhole in the shell, or head, or have a manhole.

All such vessels less than 16 in. in diameter may be constructed without a handhole, provided there are at least two pipe connections, or provided they have bolted blank flanged heads.

Threaded Openings

U-59. All pipe threads shall conform to the American Pipe Thread Standard and all connections 1-in. pipe size or over shall have not less than the number of threads given in Table U-5. For smaller pipe connections there shall be at least four threads in the opening.

If the thickness of the material in the pressure vessel is not

sufficient to give such number of threads, the opening shall be reinforced by a pressed steel, cast steel, or bronze composition flange or plate, riveted or brazed on, or a boss may be built up by an autogenous welding process for an opening not to exceed 2-in. pipe size, and for a pressure not to exceed 100 lb. per square inch, so as to provide the required number of threads.

When the maximum allowable working pressure exceeds 125 lb. per square inch, a connection attached to the pressure vessel to receive a flanged fitting shall be used for all pipe openings over 3-in. pipe size.

TABLE U-5. MINIMUM NUMBER OF PIPE THREADS FOR CONNECTIONS

Size of pipe connection, in.	1 and 1¼	1½ and 2	2½ to 4 inclusive	4½ to 6 inclusive	7 and 8	9 and 10	12
Number of threads per inch	11½	11½	8	8	8	8	8
Minimum number of threads required in opening	4	5	7	8	10	12	13
Minimum thickness of material required to give above number of threads, in.	0.348	0.435	0.875	1	1.25	1.5	1.625

Supports

U-60. *Supports.* All vessels must be so supported as to properly distribute the stresses due to the weight of the vessel and contents.

Lugs or brackets when used to support a vessel shall be properly fitted to the surfaces to which they are attached. The shearing and crushing stresses on material used for attaching the lugs or brackets to the vessels shall not exceed 40 per cent of the maximum allowable working stresses given in paragraphs U-15 and U-16.

U-61. In laying out the plates care must be taken to leave one of the stamps required in the specifications for material used, so located as to be plainly visible when the vessel is completed; or in case these are unavoidably cut out, the heat number, quality of plate, minimum tensile strength and maker's name shall be accurately transferred as to form by the pressure-vessel manufacturer, to a location where these stamps will be visible. The form of stampings shall be such that it can be readily distinguished from the plate maker's stamping.

U-62. Vessels over 12 in. in diameter subject to interior corrosion must be so arranged that the interior and exterior of the vessel may be inspected. In the case of vertical cylindrical vessels subject to corrosion, the bottom head, if dished, must have the pressure on the concave side to insure complete drainage.

U-63. Every pressure vessel shall conform in all details with these rules, and when so constructed shall be stamped with the legend provided for in paragraph U-66.

U-64. *Hydrostatic Test.* Each vessel constructed under these

rules shall be tested under hydrostatic pressure to 50 lb. in excess of the maximum allowable working pressure when same does not exceed 100 lb., and to one and a half times the maximum allowable working pressure above 100 lb., except that enameled vessels shall not be tested in excess of the working pressure.

U-65. Every pressure vessel shall be inspected at least once by a State or municipal inspector of boilers, or an inspector employed regularly by an insurance company which is authorized to do a boiler insurance business in the State in which the vessel is built, or in the State in which it is to be used, if known, which inspection shall be made when the hydrostatic pressure test is on. A data sheet shall be filled out and signed by the manufacturer and the inspector, which data sheet together with the stamping on the vessel, will denote that it is constructed in accordance with these rules. Every pressure vessel fabricated in whole or in part by a welding process, shall, when the size of the shell permits, be internally inspected before being finally closed to inspection.

U-66. Each such pressure vessel shall be marked in the presence of the inspector, A.S.M.E. Std. P.V., and with the manufacturer's name and serial number and working pressure. These markings shall be stamped with letters and figures at least 5/16 in. high on some conspicuous portion of the vessel, preferably near a manhole, if any, or handhole. These stamps shall be arranged substantially as follows:

A. S. M. E. STD. P. V.
Serial No. .....
Max. W. P. .....lb.
Mfrs. No. .....
.....
(Mfrs. Name)

The stamping shall not be covered permanently with insulating or other material. The symbol authorized for use on power boilers shall not be used on pressure vessels.

Rules for the Fusion Process of Welding

U-67. *Processes.* The fusion process, so-called, shall consist of welding by means of either the oxyacetylene process or the electric arc process, using welding wire, either bare, coated or covered.

U-68. When properly welded by the fusion process, the strength of a joint may be calculated on a maximum unit working stress (*S*) of 5600 lb. per square inch (see paragraph U-20).

U-69. The term "base metal" shall mean the metal or metals of which the vessel is constructed and which are joined together by the welded seam.

U-70. *Material for Base Metal.* The base metal of shells shall not exceed 5/8 in. thickness. All base metal shall be of good weld-

able quality and shall be made by the open-hearth process, conforming to the requirements of the Specifications for Forge Welding, paragraphs U-110 to U-125, or to those for flange and firebox classes of steel given in paragraphs S-5 to S-17 of Section II of the Code.

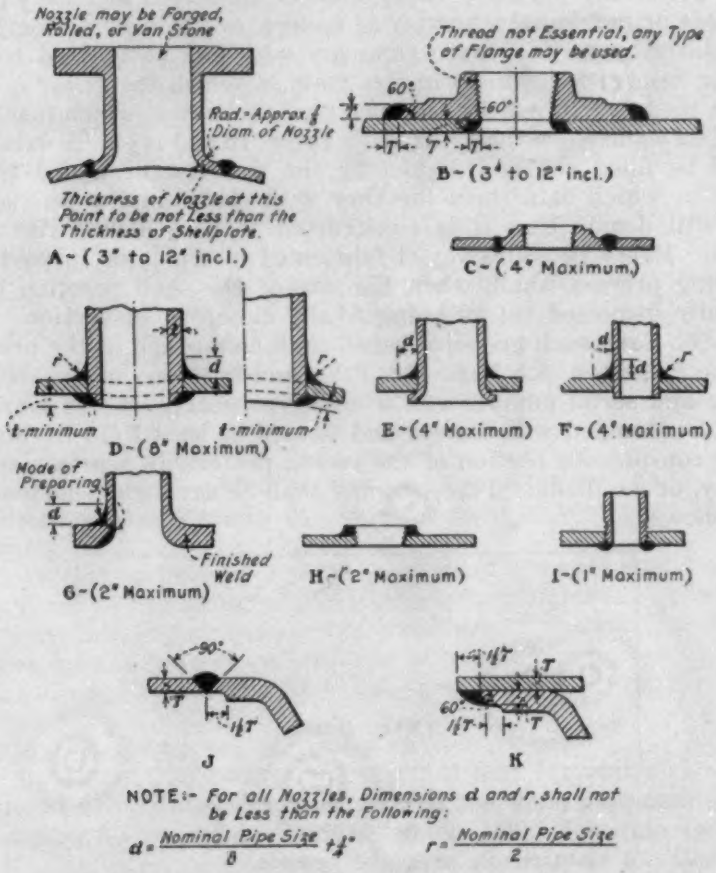
Nozzle may be Forged, Rolled, or Van Stone
Rad.=Approx. ¼ Diam. of Nozzle
Thickness of Nozzle at this Point to be not Less than the Thickness of Shellplate.
A~(3" to 12" incl.)
Thread not Essential, any Type of Flange may be used.
60°
B~(3" to 12" incl.)
C~(4" Maximum)
t-minimum
t-minimum
D~(8" Maximum)
E~(4" Maximum)
F~(4" Maximum)
Mode of Preparing
Finished Weld
G~(2" Maximum)
H~(2" Maximum)
I~(1" Maximum)
90°
J
K
NOTE:- For all Nozzles, Dimensions d and r shall not be Less than the Following:
d = Nominal Pipe Size / 8 + ¼"
r = Nominal Pipe Size / 2

FIG. U-3. METHODS OF AUTOGENOUSLY WELDING NOZZLES AND HEADS

U-71. Method of Welding. Longitudinal seams shall be of the double-V type, that is, welded from each side halfway through the sheet. Girth and head seams may be of the single-V type, that is, welded entirely through from the outside. Double-V welds shall be reinforced at the center of the weld on each side of the plate by at least 25 per cent of the plate thickness. Single-V welds shall extend entirely through the plate and shall be reinforced at the center of the weld by not over 20 per cent of plate thickness. All welds shall be of sound metal, thoroughly fused to the sides of the V for its entire depth. Sheets must not be allowed to lap during welding. In material ¼ in. or less in thickness, the longi-

tudinal seams need not be beveled. In material less than ¼ in. thick, beveling the heads will be sufficient, and the shell need not be beveled at the head seams. One side of each girth seam shall be beveled.

There shall be no valley either at the edge or in the center of the joint, and the weld shall be so built up that the welded metal will present a gradual increase in thickness from the surface of the sheet to the center of the weld.

At no point shall the sheet on one side of the joint be offset with the sheet on the other side of the joint in excess of one-quarter of the minimum thickness of the sheets, or plates.

U-72. *Longitudinal Joints.* Where vessels are made up of two or more courses with welded longitudinal joints, the joints of adjacent courses shall be not less than 60. deg. apart.

U-73. *Distortion.* The cylinder or barrel of a vessel shall be substantially circular at any section, and if necessary to meet this requirement shall be reheated, rerolled or reformed.

U-74. *Dished Heads.* Dished heads convex to the pressure shall have a flange not less than 1½ in. long and shall be inserted into the shell, with a driving fit, in excess of the full length of the flange, welded to the shell with a V'ed weld, heated to the annealing point, the shell to be constricted on the end to a diameter not less than 1 in. smaller than the original diameter.

Dished heads concave to the pressure shall have a length of flange not less than 1 in. for shells not over 24 in. in diameter. For vessels over 24 in. diameter this length shall be not less than 1½ in. It is, however, recommended that the length of flange shall be not less than 12 per cent of the diameter of the shell.

When the heads are thicker than the shell they shall be reduced in thickness as shown in Figs. U-3*J* or U-3*K*.

U-75. *Hemispherical Heads.* Hemispherical heads concave to the pressure shall have a flange not less than 1 in. long, and shall be attached to the cylinder by a butt weld.

U-76. Nozzles in heads or shells not to exceed 12 in. nominal diameter shall be of forged or rolled steel, and shall be formed and welded in accordance with Fig. U-3*A*. The nominal diameter of the nozzle shall not exceed one half the nominal diameter of the shell.

U-77. Threaded connections shall be made as shown in Figs. U-3*B to* U-3*I*. In all cases threaded connections shall be not less than extra-heavy pipe size, and shall be a snug fit when inserted into the shell plate. The nominal diameter of threaded connection shall not exceed one-third the nominal diameter of the shell.

U-78. *Hydrostatic and Hammer Tests.* While subject to the hydrostatic pressure herein before specified, a thorough hammer or impact test shall be given. This impact test shall consist of striking the sheet on both sides of the welded seam a sharp vibratory blow with a 2- to 6-lb. hammer with a handle similar to

a blacksmith's striking hammer, the blows to be struck 2 to 3 in. apart and within 2 to 3 in. of, and on each side of, the seam—the blows to be as rapid as a man can conveniently strike a sharp, swinging blow, and as hard as can be struck without indenting or distorting the metal of the sheet. During this test the shell shall be completely filled with water. Vessels fabricated in accordance with Par. U-23*a*, after the test herein specified, shall have the pressure raised to 3 times the maximum allowable working pressure, and held there three minutes.

U-79. *Defective Welds.* Welded seams, or joints, which do not pass this test without leaks, distortion, or other signs of distress, shall be corrected and a further test applied which shall be successfully passed before the vessel is accepted. Defective sections of a welded seam may be cut out and rewelded provided the value of the sheet has not been definitely lowered.

Enameled Vessels

U-97. *Material.* All pressure vessels intended to be coated with glass or other enamel shall be made of steel or iron not under 3/16 in. nor more than 5/8 in. in thickness and may be welded by the oxy-acetylene, electric or forge-welding processes. If forge welding is used the requirements of Pars. U-80 to U-90 shall be followed. All plates shall conform to the Specifications for Steel for Forge Welding, Paragraphs U-110 to U-125, and any plate not conforming thereto may be rejected.

U-98. The maximum allowable working pressure for single-shell vessels shall be determined by the following formula:

$$P = \frac{5000t}{R}$$

where t = thickness of plate, in., and R = inside radius, in.

U-99. The formula given in Par. U-36 shall be used in calculating the minimum thickness of heads necessary for the various pressures and diameters.

U-100. The ratio of diameter of the vessel to thickness of plate shall in no case exceed 320.

U-101. Any brand of welding wire which has been found by practice to give good results may be used, and may be bare, coated or covered.

U-102. Vessels of this class will be considered under two types, viz., single-shell vessels and jacketed vessels.

U-103. Longitudinal seams of single-shell vessels welded by either the oxy-acetylene or electric processes or both shall be double-V welded.

The weld on all surfaces to be enameled may be ground flush with the surface of the plate.

U-104. Jacketed or double-shell vessels may be of two types,

one in which one of the heads of the inner vessel forms the sealer apron for the jacket, and one in which the sealer apron is joined to the shell of the inner vessel at some point between the heads, forming a partially jacketed vessel.

U-105. The inner shell of a jacketed vessel, when not stayed to the outer shell, should be of such construction as to safely withstand both the pressure in the jacket which tends to collapse it, and the pressure on the inside which tends to burst it, when either of these pressures act singly.

U-106. The longitudinal seam of the jacket shall be double-V welded. The circumferential seam in the jacket joining the head to the shell may be single-V welded.

U-107. In jacketed vessels where the sealer apron is welded to the shell of the inner vessel, and also where the sealer apron is welded to the shell of the jacket, the weld may be made from outside only, provided the thickness of the metal deposited is equal to or greater than the thickness of the apron or plate.

U-108. In jacketed vessels where the top head of the inner shell forms the sealer apron, the head may be welded to the shell of the inner vessel from the side only, provided the thickness of the weld after grinding is equal to or greater than the thickness of the shell.

U-109. All cylinders shall be rerolled after welding.

Specifications for Steel Plate of Flange Quality for Forge Welding

U-112. *Chemical Composition.* *a.* The steel shall conform to the following requirements as to chemical composition:

Carbon	for plates ¾ in. or under in thickness	not over 0.15 per cent
	for plates over ¾ in. in thickness	not over 0.17 per cent
Manganese		0.35 to 0.60 per cent
Phosphorus	Acid	not over 0.06 per cent
	Basic	not over 0.04 per cent
Sulphur		not over 0.05 per cent

U-115. *Tension Tests.* *a.* The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45,000
Yield point, lb. per sq. in.	0.5 tens. str.
but in no case less than	24,000 lb. per sq. in.
Elongation in 8 in., per cent	30

b. The yield point shall be determined by the drop of the beam of the testing machine.

U-116. *Modifications in Elongation.* *a.* For material over ¾ in. in thickness a deduction from the percentage of elongation specified in Par. U-115 (*a*) of 0.125 per cent shall be made for each increase of 1/32 in. of the specified thickness above ¾ in.

b. For material under 5/16 in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Par. U-115 (*a*) of 1.25 per cent shall be made for each decrease of 1/32 in. of the specified thickness below 5/16 in.

Welding Practice and Inspection in Shipyards*

W. P. HOUGH†

This paper is written with a view of presenting the methods used in shipyards for the inspection of electric welding; also for testing the skill of operators.

Naturally the views as presented are based on actual performances in certain yards. We have, however, attempted to make our description of methods so general that we feel sure they represent, in a great measure, the practice in shipbuilding industry as a whole.

The development of welding has been confined in shipyards, mainly to electric welding. Acetylene welding on steel has not been developed to the extent that it has in some other industries, therefore, our discussion will deal almost entirely with electric welding.

The use of electric welding in a shipyard does not present the unlimited field that we might expect. This is due to the fact that the different bureaus of the United States Navy Department, The American Bureau of Shipping and Lloyd's Classification Society do not allow electric welding except in certain well defined cases and this welding can only be carried along under the close inspection of their respective representatives.

Electric welding in the shipbuilding industry is divided into two general classes:

First: Work in connection with construction and such work as the attaching of fittings, etc., to the ship's structure. This class of work has been very well described in the various papers presented by Mr. Ewertz.

Second: Work in connection with correcting defects in material. This class covers the reclamation of steel castings by welding.

In practically all cases on this type of work before welding can be started, permission must be received from the inspector. On steel castings the defective area must be chipped out and cleaned down to good metal; the casting in this condition is presented for inspection. If the cavity is well defined and is not too large usually the necessary permission is given to weld. After welding the casting is given careful surface inspection and hammer test. Wherever possible a hydrostatic test is made to prove the tightness of the weld.

It might be well to point out at this time the absolute necessity of obtaining the permission of the resident inspector before welding. Many castings have been condemned because they have been welded without authorization. It is necessary that the inspector

*Presented at the Annual Meeting of the A. W. S., April, 1925.
†Supervisor of Electric Welders, Fore River Plant, Bethlehem Shipbuilding Co.

see the nature of the defect before welding is allowed. As a rule, inspectors have none too high an opinion of welding and we find it very desirable to acquaint the inspector with all the conditions which have made it necessary to weld.

Preparation for Welding

On plates, angles, bars and material of like nature, we find a 90 deg. bevel gives the best conditions for welding. On castings where foundry defects appear and where the shape of the material to be welded is of such a nature that no standard can be set, it is necessary that the welding supervisor be consulted as to just how the material should be prepared for welding. All surfaces to be welded should be thoroughly cleaned and should be free of all foreign matter, such as: oxides, rust, paint, oil and grease. Too much importance cannot be placed upon properly cleaning the surface to be welded.

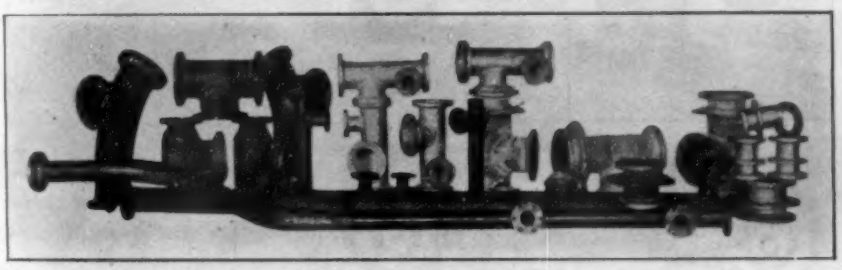

Fig. 1. Welded pipe fittings for high pressure oil lines built up by welding steel parts

Length of Arc

Due to the various classes of work to be welded it is not possible to set a hard and fast rule for the proper length of arc. In general we attempt to maintain an average length of arc of about ⅛ in. A skilled operator will, sub-consciously, adjust the arc to the proper gap to obtain the best results. In finishing a weld the operator will quench the arc by slowly closing the gap, thereby filling up the crater formed by the arc.

On light metal work where excessive transfer of heat is likely to warp the material, it is necessary for the operator to use good judgment in controlling the length of his arc in order that the heat transmitted to the welded metal will be kept to a minimum.

Penetration

Penetration is controlled by the depth of the crater formed by the arc on the metal to be welded. The depth of this penetration is controlled, in a great measure, by the thickness of the stock. On plates upward of ¼ in. in thickness the crater should show a penetration of about ⅛ in. Also the depth of this crater depends to some extent upon the diameter of welding wire used; the larger diameter requires a deeper penetration.

Fusion

Fusion of the added metal with the base metal takes place the instant the current flows across the gap at the electrode. Proper fusion of metal depends, first: upon forming a suitable crater in the base metal; second: upon the proper speed at which metal is allowed to flow into this weld; third: the proper care in floating off the slag or oxide.

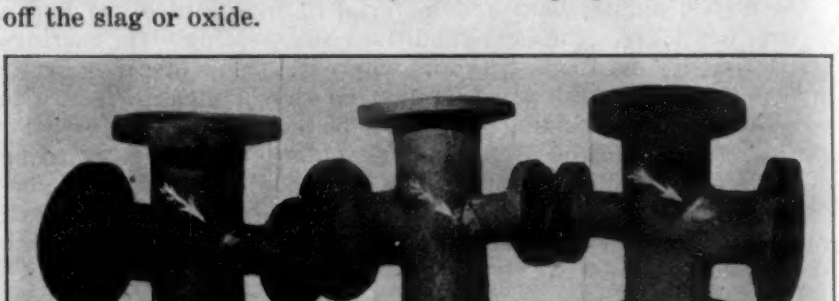

Fig. 2. Repairing castings

These factors are controlled by the skill of the operator. A good operator can tell by the appearance of the molten metal, and also by the sound or snap of his arc, whether or not he is getting proper fusion.

Porosity

Electric welding is essentially a casting operation and we expect a steel weld to show much the same characteristics as a steel casting. As a result we do not expect to obtain a close grain structure such as would be found in wrought iron or forged steel.

On special jobs where we are particularly desirous of having a weld show no porosity we find that by peening the weld while still hot we can close in the grain and obtain a very uniform structure throughout the weld. We feel, however, that in most cases a weld, made by a skilled operator, can be made perfectly water-tight without peening.

We have been able to make pipe fittings, built up of welded pipe, sufficiently tight to maintain the hydrostatic pressure of 4000 lb. per square inch without peening.

Visual Inspection of Finished Jobs

The appearance of a finished weld is often deceiving and unless the inspector has some knowledge of the art of welding he will be unable to detect, by appearance, whether or not the weld is sound. A smooth looking weld is not necessarily a good weld; also a weld which has a rough appearing surface may be perfectly good.

The slag and oxides formed in welding metal, fuse first and

come to the surface of the weld. A weld of two or three layers in thickness will be covered by a coating of this slag which gives a very rough appearance. However, if this coating is chipped off a very good weld may be found underneath this surface. There are, however, certain things which a skilled welder can observe in a weld which will give him an indication as to whether or not the weld has been properly made. In a good weld the deposited metal should lay flat with the edge forming an open angle with the base metal. Also a good weld will show an even surface with no excessive humps and hollows. A weld that shows a tendency of the deposited metal to pile up on the base metal indicates that the metal has been under-heated and has not been allowed to flow properly.

In addition to a visual inspection it is highly desirable, whereever possible, to subject the weld to a physical test even to the extent of occasionally testing a sample to destruction.

Photographs

Photographic records are kept of unusual welds for future reference. From time to time microscopic photographs have been taken of specimens to show the structure of the welds.

Testing Skill of Operators

All electric welders are in one organization and under one group of supervisors irrespective of in what departments they are doing work. The supervisors are men who have been trained in welding schools and who are still undergoing special outside instruction. Any welding job of special importance is under the personal supervision of one of these supervisors.

It has been found desirable to make welders of men already employed in the yard. Special attention is given to the selection of men who have a knowledge of the work on which welding is to be applied; on ship work, men with shipfitting experience are usually selected. For welding castings, men with some machinist or engineering experience are chosen. In selecting a man to learn welding, particular attention is given to his reliability and his capacity for taking pride in his work.

When an operator starts his training, he is first put with a skilled welder to observe the process of welding. After a while the welder will give the new operator a chance to handle the arc. The next step is to put the new operator on individual work under the supervision of one of the welding supervisors. He remains under the constant instruction and observance of the supervisor until he has been able to show sufficient skill to be allowed to do production work. When put on production work he is constantly checked up as to weld failures, poor looking workmanship, etc. It is then that he begins to build up his reputation for craftsmanship.

We feel that the greatest single qualification for a good welder is the development of a personal pride in craftsmanship. We

stress every effort to put this individual pride into every welder. If the operator does not respond to such treatment he is transferred from the welding department. Wherever it is possible to test welds an effort is made to have these tests carried on in the presence of the man who performed the work. Every welder is taught the importance of up-building a personal reputation.

We have not as yet been able to devise any system of inspection which will absolutely assure us of results for all classes of work. The individual ability and integrity of the operator is our surest check on the quality of welding. We feel that the building up of confidence in electric welding on the part of the customer, or inspector, can best be accomplished by the development of individual responsibility and pride on the part of each welder.

Determining and Increasing the Skill of Welders*

G. O. CARTER†

Proper fusion of the base metal and depositing of good weld metal is the final step and probably the most important one in the welding procedure. Use of the right materials, proper design and preparation of the joint and adherence to correct practices are also most important in making a satisfactory weld. If any of these steps are not properly taken the resulting weld will be less than 100 per cent, but the first two mentioned are of foremost importance.

It is worthy of frequent emphasis that a blowpipe user who does not deposit good weld metal or one who does not bring the base metal to fusion will not make a good weld. It is not difficult to dispose of the man who falls completely short of this first essential, but many welders do not even know that they fall a little short, not dreaming that their welds are deficient in penetration or that the deposited metal is burnt or that both these evils appear in their work.

For these reasons length of welding experience is not a correct guide for selection of welders. Nothing but an actual proficiency test will suffice to properly qualify a welder.

The first thing to be determined is that the welder deposits sound weld metal. In order to do this he must be using a neutral flame. He must also be holding his blowpipe at the right distance from the work and must be adding the weld metal in the proper manner into the molten bath.

Fortunately, it is very easy to determine whether these steps are being correctly done. Merely bend a test strip in a vise. This

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*Presented at annual meeting, A.W.S., April, 1925.
†Consulting Engineer, The Linde Air Products Co.

procedure, which has been frequently described at our meetings, will tell in a few seconds whether or not a welder is depositing sound metal. If the welder was flustered while he was making the weld, it may be a good thing to let him take some pieces to be joined and make welds without anyone bothering or watching him. If his welds, made under those conditions, seem to be good he should then be made to realize that the test is not to reject him, but is intended to *qualify* him. He should then be asked to qualify under proper observation.

It is important that a welder should be able to make a good weld when being observed, because inspectors, foremen, engineers and others may be expected to observe a welder while he is in the midst of production work. It is recognized that many welders do get nervous when being watched and it is not uncommon for a welder to put out his flame and pretend to be adjusting his work or to leave his welding station in order to avoid handling the blowpipe under observation. The sooner the welders become accustomed to having their work watched the better off they and the welding process will be. Therefore, although we should be patient with such men, we should try to point out to them that they must overcome their objections to being observed and learn to keep on just as though no one were around.

On ordinary non-repetitive jobs it would hardly pay to set up means with which to coach a man who cannot deposit 100 per cent sound weld metal, but under conditions where a large gang is being recruited for repetitive work it will pay to provide the means of testing and teaching and then to study such individuals. A talk with the candidate may show that he has had experience in other lines of welding, but does not have such broad experience as to qualify him for the particular kind of work which is under consideration. Another friendly talk may show that the second candidate has watched someone else use the blowpipe and thinking that it was easy had occasionally used it himself. Because the surface appearance of the deposited metal seemed satisfactory, he believed he was making a weld. Such a man, given the right handling by an employment manager, may develop into a very good welder because he undoubtedly has the desire to weld and is probably in the mental state where he is ready to learn. This is more of a personnel matter than one pertaining to welding itself.

The second phase of testing is to determine whether the joint has correct fusion and penetration. A man may be depositing sound weld metal and still not be fusing it with the base metal. The ability of any given man may lie between complete failure to fuse, to that proficiency where he only occasionally fails to penetrate. The poor welder who does not fuse the metal at all is practically in the same state as the man who badly burns his weld metal. Only a very special condition, where a big force is being organized from a small labor supply, should warrant any time being spent on coaching such a man.

About half of those who apply for welding work in reply to ordinary ads fall down badly when the specimen welds are tested as to penetration. In most cases fusion extends only about half the thickness of the base metal. Occasionally test pieces will show that a welder fuses pretty well all the way through for an inch or so of the joint and then only partially for another inch or two. This difficulty can often be discovered by simply looking at the reverse side of the test piece, as beads of sound weld metal will appear along the bottom of the V for short stretches, then the butting edges of base metal itself will show.

Unfortunately welds which are half penetrated with good deposited metal or which have about half good stretches and half poor stretches are usually strong enough to withstand almost any service where single riveted joint would be suitable. As this covers such a large percentage of mechanical construction, there are many men who are given the reputation of quality of workmanship, but they rightfully can not be called competent welders.

This class of welder can usually be coached so that in a few hours he is making an entirely satisfactory weld, as shown when his test pieces are either pulled apart or bent.

In many instances it is hardly necessary to coach men who have been doing reasonably satisfactory welding for periods of months and years, because once they have observed the quality of their workmanship in the bending test, they will run such tests periodically for themselves. When a test strip is bent away from the bottom of the V the fracture shows most conclusively just where there has been lack of fusion or lack of penetration.

In coaching welders it is not always best for the teacher to use the torch himself. After insisting on the welder modifying his flame (if trouble has been experienced on that account) the difference in quality of deposited metal should be obvious when the strip is bent. The effect of proper application of the heat to the base metal, so as to result in thorough fusion, should also be apparent in the test. When these improvements result from the welder's own efforts, merely by the modified use of the blowpipe, he should readily see that his unsatisfactory preliminary test-welds were due to his failure to follow correct practices.

Whenever the character of work for a welder is materially changed, he should be called upon to make a qualifying weld. If materials are changed, such as from steel to cast iron, to aluminum, or to other metals; if a radical change is made in the thickness of material being welded, say from 10 gage to $\frac{3}{8}$ in. or from $\frac{3}{8}$ in. to $\frac{5}{8}$ in.; if any procedure is changed, such as welding unbeveled $\frac{1}{4}$-in. material when welder had been previously working on beveled material. if there be any radical change in the spacing; or if a change in character of the filler rod is made anything of this sort should demand a new test and demonstration of the worker's fitness under the new conditions. This may seem a little irksome to many who have not given a lot of study to this subject and who

have not seen the effects of ignoring such changes, but it is essential to obtain consistently good results.

From a business standpoint, the speed of welding is always an important factor. Unless the management can keep an eye on the welders and also encourage them to produce a good day's work, the preliminary test should specifically provide for a satisfactory weld at better than some reasonable minimum rate to be set by the examiner.

It is obvious, of course, that if an employer desires to have welders who do turn out a large quantity of thoroughly satisfactory welding, he will find it much more difficult to obtain sufficient employees. As time goes on, however, the number of qualified welders will increase and many of them will be able to make very satisfactory welds at a high rate of speed.

In this connection it is interesting to note that there is a limit to speed of welding which can be done on any given thickness of steel when using a single oxyacetylene flame. This maximum speed is set by the fact that with too large a flame, the skin of the base metal is brought to a molten condition, but the underlying metal does not become plastic, which is necessary for satisfactory oxwelding. Therefore the maximum speed is that speed wherein the greatest volume of flame brings the abutting metals to fusion without "burning" them.

Fusion Welding and Cutting as Practised on the Atchison, Topeka & Santa Fe Railway*

E. E. CHAPMAN† AND H. H. SERVICE††

Scope of Work

The Santa Fe Railway System in its various shops and roundhouses is equipped for handling work by electric, oxyacetylene and thermit welding processes, and instructions are available in the various shops for proper supervision and control of the work so that satisfactory service may be obtained. The various practices for each process have been standardized for the system as the result of extensive investigation work which began on this road about 1908. Even at that time, while fusion welding was but little understood, it was realized that this type of tool for use in building and repairing might be a wonderful help, but could easily be made a two-edged sword, which if not properly controlled would do

*Paper read by Mr. Walter Bohnstengel, Assistant Engineer of Tests, Atchison, Topeka & Santa Fe Railway, before the Chicago Section of the American Welding Society at Chicago, March 6, 1925.

†Engineer of Tests.

‡Supervisor of Welding Equipment.

so much damage that it would offset the advantages which would accrue from its use.

Welding Folio

With this in view, data on new classes of work were carefully compiled by the supervisor of welding equipment and in compliance with instructions from Mr. Purcell, assistant to the Vice President in charge of mechanical matters, these data were issued as a standard pamphlet, designated "Oxyacetylene and Electric Arc Welding Folio," for the instruction and guidance of those who have direct supervision of welding in the various shops and roundhouses on the system. This welding folio is kept up to date by frequent revisions and as better methods are devised and better welding material are developed, and tried out with satisfactory results, they are included in the folio.

Boiler Welding

In order that the fundamental principles of this art may not be violated the following general rules are stated for work concerning boilers and pressure containing vessels:

1. Autogenous welding will not be permitted on any part of a locomotive boiler that is wholly in tension under working conditions; this to include arch or water bar tubes.

2. Staybolts or crown stay heads must not be built up or welded to sheet.

3. Holes larger than 1½ in. in diameter when entirely closed by autogenous welding must have the welding properly stayed.

4. In new construction, welded seams in crown sheets will not be used where full size sheets are obtainable. This is not intended to prevent welding crown sheet to other firebox sheets. Side sheet seams shall be not less than 12 in. below highest point of crown.

5. Only operators known to be competent will be assigned to fire box welding.

6. Where autogenous welding is done, the parts to be welded must be thoroughly cleaned and kept clean during the progress of the work.

7. When repairing fireboxes, a number of small adjacent patches shall not be applied, but the defective part of sheet shall be cut out and repaired with one patch.

8. The autogenous welding of defective main reservoirs is not permitted.

9. Welding rods must conform to the specifications.

Autogenous Welding Don'ts

Inasmuch as there are a great many things to be avoided in the use of autogenous welding, due either to rules of the American Association or the Interstate Commerce Commission, a series of prohibited practices have been established and added to as circumstances demand These constitute a series of *Dont's,* most of which

are self-evident, while others may be new and consequently overlooked, so they are cited here to show the detail of supervision exercised to keep an operator out of trouble and do good work. Our present list follows:

Don't weld cracks in boiler shells.

Don't weld patches in boiler shells.

Don't weld patches in knuckles of back heads and other parts of boilers which are wholly in tension under working conditions.

Don't weld grooves or pitted parts of boiler shell or firebox (remove the defective portion and apply new material).

Don't weld arch tubes.

Don't weld cracks in firebox sheets which are over 12 in. long. Apply a patch.

Don't weld cracks in firebox without removing the staybolts from holes into which the crack extends.

Don't apply excess metal. It is a waste of time, strength, and material.

Don't weld staybolts.

Don't weld leaky rivets or staybolts.

Don't weld stay rods for boilers.

Don't weld over cracks in fireboxes unless they are properly chipped out.

Don't proceed to weld any job until it has been properly prepared and the conditions are such that you can produce a good weld.

Don't burn out studs in shells of boilers when the size of studs is less than $\frac{5}{8}$ in. in diameter.

Don't weld up solid drain plug holes in air reservoirs. Apply a pipe plug.

Don't weld patches in the unstayed surface of air drums and reservoirs.

Don't weld oil tanks until they have been thoroughly cleaned.

Don't forget to weld on both sides of the seam when it is possible to do so

Don't weld sharp or worn flanges on tires of wheels.

Don't weld cracks in main rods, side rods, or crossheads.

Don't weld on piston rods.

Don't cut the keyways in piston rods.

Don't weld cracked or worn axles.

Don't weld locomotive drawbars which are cracked.

Don't weld knuckle pins which are worn or cracked.

Don't weld on main or crank pins which are worn or cracked.

Don't weld over dirty or greasy metals. Have same thoroughly cleaned.

Don't weld broken frames until the proper allowance for contraction has been provided for.

Don't burn off cast iron castings which can be machined or chipped economically.

Don't burn small holes in plates or castings which should be drilled and can be drilled or punched more economically.

Don't cut plates which can be sheared more economically.

Don't weld arch bars which are cracked or worn.

Don't weld tension members on car or coach castings when the tension member is fractured more than 40 per cent of the original or total cross section of tension member.

Don't weld cracked or fractured grab irons, equalizers, sill steps, brake staffs or wheels.

Don't weld fractured coupler bodies, knuckles, knuckle pins, locks, lifters, and throwers.

Don't weld truck frames, side frames, bolsters, body bolsters, while under cars, when load is on same. Have same taken from under car and weld properly.

Don't start electric welding machines unless you know all the connections are tight and that machine is in good condition.

Don't start welding until the positive or ground wire is firmly secured close to the work which is being performed.

Don't connect ground or positive side of welding circuit to water, steam and air pipe lines.

Don't start welding until you have the proper welding wire.

Don't let your machine or equipment get into a dirty condition. Once cleaned it is easily maintained in such a condition.

Don't start welding or cutting until you have protected yourself and other workmen from the electric arc rays and sparks.

Don't start welding until first having protected your eyes and face with a suitable hood or welding goggles.

Don't leave welding wire or rods on locomotives or tanks or other equipment.

Don't allow welding wire to be used for other purposes than welding.

Don't waste welding material or scatter same over the floor.

Don't forget to brush off all oxide from work after each electrode has been consumed.

Don't leave your job unless you shut off your machine, or disconnect the leads from the work.

Don't allow the negative side of your circuit to remain in contact with the positive side of circuit more than one minute. This may result in heavy damage to the machine.

Don't use leaky equipment. Have same repaired.

Don't use leaky gas hose.

Don't use trimo wrench for tightening connections. Use wrenches assigned for that purpose or a monkey wrench.

Don't use oil on gas hose or connections. It will cause explosions.

Don't allow trucks to run over gas hose. Apply a hose bridge.

Don't allow hose or welding leads to remain scattered around the floor. Keep them neatly coiled.

Don't use gas hose without clamps, but firmly secure hose with clamps at all connections.

Don't throw sparks from cutting blowpipes in the direction toward hose. It is liable to burn your gas hose and cause a fire.

Don't leave your work until all pressure valves are closed.

Don't return gas cylinders as empty when there is sufficient gas remaining in cylinders to perform a job.

Don't let empty cylinders stand around. Return them to store department immediately.

Don't let defective welding equipment accumulate. Have same repaired immediately.

Don't let burner tips become dirty or come in contact with molten metal. It sometimes causes disastrous back-fires.

Don't use larger size cutting nozzles or welding heads than is necessary to do the job.

Don't use welding and cutting blowpipes for pinch bars or hammers.

Don't look or hunt for gas leaks with a lighted torch. Use soapy water and a brush or piece of waste.

Don't use oily packing on oxygen valve stems. Use lamp wick and glycerine.

Don't handle oxygen or acetylene cylinders roughly. They have been known to burst on account of rough handling.

Don't store oxygen or acetylene cylinders close to open fire, hot boilers, radiators or hot sun rays. Store in room at a temperature of about 60 deg. Fahr.

Don't heat or warm gas regulators with open fires or red hot irons. Use steam or hot water.

Following this list of precautions and prohibitions are some general instructions to be observed in welding, a few of which will be cited to show their scope.

General Welding Instructions

Carefully fit all patches or seams, allowing not more than one-fourth or less than 3/16 in. space at the bottom of the "V" opening. All edges to be welded must be beveled to 45 deg. All welders, and those preparing seams for welding must be provided with a gage for testing the bevel and opening between the plates. When the opening between the plates closes to less than 3/16 in., welding must be stopped and full opening made by chipping with hammer and chisel. Do not burn the edges of the plates to enlarge the opening.

Keep Work Clean

No piece of work that is to be welded is properly prepared unless it is thoroughly clean and free from all grease, rust, scale or other foreign substance. The weld must be made on clean, bright metal, and that condition must be preserved throughout the welding operation. Proper tools will be furnished to keep work clean,

and all are again advised that a reliable weld cannot be made unless the parts being welded are maintained bright and clean throughout the operation.

To Prevent Accidents—Electric Welding

Operators should keep face and hands well protected from the welding rays and should not attempt to weld without having the eyes protected with suitable hood, which will be furnished for that purpose. All welding operations should be screened from other workmen. Insulation on all lead wires shall be maintained in good condition and must be kept dry.

To Prevent Accidents—Oxyacetylene Welding

Do not use oil or grease in any way in connection with regulators, because oxygen under high pressure in contact with oil will fuse and destroy the regulators and gages.

Oxygen Regulators

Before attaching regulator to cylinder, open cylinder valve slightly to blow out dirt from the passages. Close valve tightly and quickly.

Attach regulator firmly to cylinder and *fully release* the diaphragm spring by turning regulating screw to the left before opening tank valve. Open tank valve gradually, and while doing so do not face the gages, but stand to one side of the regulator, because the sudden pressure on the gage may break the glass. Oxygen tank valves should be screwed open as far as they will turn.

In adjusting oxygen regulators to obtain working pressure, turn regulating screw to the right, and close oxygen valve on blowpipe. Then slowly turn the regulating screw to the right until proper pressure shows on the little gage.

Not under any circumstances should oxygen, acetylene, Blau, or Pintsch gas containers be used for any other gases than that for which they are assigned.

Do not try to equalize pressure from oxygen container into any other container or cylinder other than that which has been provided for oxygen only.

Do not use any other vessel or container for storing or equalizing pressure of acetylene gases other than that which has been provided for. The same rules also pertain to Pintsch and Blau gases.

When making connection to any container or cylinder which contains any of the above mentioned gases, it is very important that all connections be free from grease or foreign matter and that they should be thoroughly cleaned. If it is necessary to clean connection with gasoline, same should remain in the open for at least one hour after being wiped dry in order that gasoline remaining on interior connection will have evaporated, so that there will be no danger of explosion or fusion after connection is made.

All gas hose which is used for oxygen and acetylene should be

thoroughly inspected once a week for leakage, perforated hose, poor connections, oil soaked, and other defects. If hose is oil soaked, it should not be used for any of the above mentioned gases. All pipe lines and valves should be inspected where permissible, and when found defective, repairs should be made immediately same as gas hose.

All acetylene generator houses or plants should be kept clean and no oily waste or other inflammables allowed to remain around on floor, cupboards, etc.

Oxygen manifold pipes and connections should be kept in proper mechanical repair. If connections become defective they should be returned to Topeka, care of Store Department, with requisition covering the repair and return of same.

If diaphragm washers in acetylene or oxygen regulators become defective, do not use rubber gasket, but return regulator to Topeka with requisition covering repairs.

Any disregard of the above rules may be very hazardous and may possibly cause serious injury or loss of life.

These are followed by safety suggestions and many pages of rules and instructions, numerous sketches and blue prints, so that a man out on the desert or out of way places, away from supervision can read the law for himself.

Welded Test Specimens

In order that officials in charge of welding and the welders themselves may know what kind of welding is being done from month to month, it is the practice of Santa Fe Railway to have each welder furnish a test plate monthly to be made in accord with the following instructions:

Secure two pieces of boiler steel ⅜ x 2½ x 9 in., bevel one end of each to form a 90 deg. angle between them, place the two plates in a convenient position for welding with 3/16-in. opening at the bottom of the "V" and make the weld from the top side only, reinforced a maximum of 20 per cent over stock size, if welder desires this much reinforcement to produce the best weld he is able to make.

It will be noted that in this test plate the weld is allowed to be reinforced 20 per cent over stock size, more than that is milled or ground off, and plate to be welded only from one side, in order that the welder can approximate the condition of welding a side sheet or its equivalent in a firebox. The welder is instructed not to forward any weld for test unless he is satisfied that it is the best he can make, and representative of the work he does. These welders are then rated according to the percentage strength of their weld which is based on the thickness of the original stock, and a strength of 60,000 lb. per square inch. It is the desire to have welders simulate actual working conditions as nearly as possible, and it is also endeavored by the foreman to have the welder complete his work at the original heat and avoid the plastering

over of metal incident to reworking and consequent weakening of the original weld. From the test data thus obtained the foreman has sufficient information at hand to judge the welder's ability to produce good work and it will justify him taking proper steps for keeping the welding up to a high standard by correcting the faults or assigning only the men who are able to make satisfactory welds to the more important welding operations.

Tests have also been made to determine the relative efficiency of welded specimens to the original stock, under vibration or alternate bending, but this is a comparative proposition and not one that can be used as a regular control.

Welding Efficiency

An analysis was made of specimens tested for the years 1920 and 1921 to show the average efficiency of welds produced by welders having different years of welding service and the results are shown in Table I

TABLE I

Years Service as Welder	Welded Specimens Tested		*Efficiency of Weld—Per Cent	
	Gas	Electric	Gas	Electric
Less than one	195	147	75.8	90.6
One	93	81	89.2	93.2
Two	177	131	85.8	92.9
Three	78	72	84.4	95.2
Four	47	10	90.6	96.9
Five	27	..	96.7	...
Six	4	6	98.3	101.0
Seven	3	9	74.6	94.9
Eight	16	..	82.4	...
Nine	7	..	89.6	...
Total	647	456	Ave. 86.7	95.0

*These efficiencies are values based on a tensile strength of 52,000 lb. per sq. in., the minimum value allowed in specifications for firebox steel.

It is noted that for the six and seven years welding service the value showed a great deal below the average which was due to a poor welder working in these two groups, but the indications are that the longer the service the greater the skill shown by operators. It will also be noted from this tabulation that for strength alone the electric welding shows up better than the oxyacetylene welding. However, for the year 1923, a check of this relation shows that due to improvement of the kind of metal used for welding with oxyacetylene the results of the latter are about on a par with the electric welding for strength.

The results obtained in four of our largest shops and in four of the largest roundhouses of the system are shown for the last three months of the year, October, November and December, 1924, in Table II.

It will be seen from these figures that a butt welded seam with a maximum reinforcement of 20 per cent of stock averages well

TABLE II

Shops	Welded Specimens Number Tested. Gas	Elec.	Specimens* Broken Outside of Weld, Per Cent. Gas	Elec.	†Efficiency, Per Cent Specimens Broken in Weld. Gas Min.	Ave.	Electric Min.	Ave.
Topeka	29	46	24	24	77	101	75	96
Albuquerque	63	32	62	53	57	99	75	101
San Bernardino	31	34	45	38	84	104	88	104
Cleburne	16	9	63	33	68	90	83	98
Total	139	121	..	..	..	..	..	..
Minimum	..	..	..	..	57	..	75	..
Average	..	..	50	37	..	98	..	99
Roundhouses								
Winslow	9	9	56	33	101	108	98	105
Amarillo	8	8	75	75	103	103	78	89
Newton	22	32	46	22	80	99	88	100
Shopton	25	22	52	36	83	98	79	103
Total	64	71	..	..	..	..	..	..
Minimum	..	..	..	..	80	..	78	..
Average	..	..	53	34	..	100	..	101

*This column also includes welds which showed 60,000 lb. per sq. in. tensile strength.

†Efficiency based on firebox steel, 52,000 lb. per sq. in. minimum tensile strength.

above the 45 or 50 per cent efficiency allowed for single riveted seams.

It is believed that for a large railway system like the Santa Fe too much stress cannot be laid on demanding of welders that they produce the proper strength of welds as shown by their test specimens so that both the management and welders may know when they are doing acceptable work. The test pieces are returned to originating shops and the results discussed with the individual men by the foreman in charge. The system supervisor of welding equipment and service company representatives also go over the results of weld tests with the men and make suggestions for the betterment of the service.

From this it will be seen that our railway management exercises a systematic control over autogenous welding operations, especially as it concerns the welding of boiler and tank steel plates. This, of course, is only one phase of the rather extensive use of these welding methods and the periodic control can easily be exercised, but there is a very extensive amount of work where such control cannot be so applied. Problems, such as best procedure and method of welding locomotive frames, bolsters, couplers, cylinders, where heating and subsequent annealing are required, and many similar questions require careful service observations or comparative tests. The question arrives as to whether it is practical to weld certain kinds of material, whether hot or cold, whether to use cast iron or steel rods for welding material, and with such questions raised many tests have been conducted to increase the list of *"Dont's"* for anything not prohibited is assumed to be permissible.

Early Tests

It would be presumptuous to attempt to present details of various tests, but it may be of interest to point out the purpose and nature of several tests conducted on our lines and the conclusions that followed. They will be taken up in chronological order so far as possible, so that you may understand the development of the work in its natural order, and see the scope of our tests if not all the details.

In October, 1909, Mr. Purcell, then superintendent of Topeka shops, stated that some freight car truck frames had been welded with the acetylene process and he wished to know the strength, asserting that if they could be made as strong as originally, about $20 per frame could be saved. A hydraulic jack was used to apply a pressure of 25,000 lb. without producing failure of the welded member and the opinion was expressed that such a method of welding truck frames will prove very satisfactory. The file does not reflect the performance of the weld in service as is so often the inevitable result when material or appliances are put in service on a large railway system and removed at some distant point, where identification is lost.

In May, 1910, two welded pieces of boiler steel were tested, showing an ultimate strength of 48,100 lb. per square inch, and elongation of 2 per cent for the one and 28,800 lb. per square inch and zero elongation for the other, or an efficiency of 93 per cent and 55 per cent respectively for the two welds based on 52,000-lb. steel.

In April, 1911, a test of a Thermit weld was made, showing an ultimate strength of 45,680 lb. per square inch and an elongation of 7 per cent. These were really single tests and it is pointed out here that our method of investigation has been changed, as well as the details of welding process, for now our conclusions are not based on a single test, but rather on a series of them that require time, but eliminate the factor of chance to a large extent.

Early in 1912 some tests were made to determine the merits of welding boiler flues into the flue sheet as compared with the expanding and beading which was the standard at that time and results were favorable to welding with some changes of detail as warranted by service.

In August, 1912, Mr. Purcell, who had assumed his present duties, requested that a firebox crack 18 to 20 in. long be welded with the acetylene process and tested in comparison with the same sheet not welded. Four specimens were pulled, showing a unit strength of 29,560 to 39,800 lb. or 57 to 77 per cent efficiency with the conclusions that the strength of a joint welded by the autogenous process is more than 50 per cent of the original strength of plate, but great care should be used in welding the fractured edges, otherwise the two pieces joined will not be bonded together sufficiently to insure a proper steam joint. At that time different de-

grees of "V" opening between ends were also studied. A little later in the year some tests and analyses of welds were made to show whether there was any difference in the use of Blau gas as compared to acetylene. These tests were followed by various tension tests and chemical analysis of welding material, including Swedish iron, low carbon, high carbon and Vanadium steels. The results of tension tests at best would be a questionable index of the strength of weld because the rods may be of different hardness and strength due to physical condition which would be lost when cast in a weld. In 1917 four tension test specimens were welded under different pressure conditions, one using 21 lb. oxygen and 5 lb. acetylene, the other 9 lb. oxygen and 9 lb. acetylene with no marked difference in the strength of the weld.

Recent Test on Rails

In 1920 some experiments were made on our lines to determine the practicability of welding on steel rails. A short time previous to the inception of this test some broken crank pins had been received at the laboratory, where the wheel fit had been built up by autogenous welding and the fracture started at the edge of the welded surface. As a result a test was made to determine the effect of gas and electric welding on the strength of rails as applied in building up battered ends and driver burns, and also the effect of gas burning bolt holes in the web of rails as compared to the regularly drilled holes. In the investigations old rails were used that had been removed on account of service defects, and about 25 rails were tested, making 6 to 18 drop tests on each, as representing the rail in natural condition, driver burned, gas welded, electric welded and holes burned through the web and head heated for various periods of time with the welding torch. The conclusions drawn from these tests were as follows:

1. Autogenous welding on the head, like building up of low spots caused by driver burns, usually weakens the rail to shock load, especially when placed in tension, but in cases of favorable chemical composition, i.e., low carbon and low manganese, no reduction, and even some increase in strength, results from gas welding.

2. Welding of surfaces that are subject to compression or wear only, such as battered ends of rails or crossing frogs may be done with reasonable safety.

3. Burning of holes instead of drilling through the web produces severe strains that seriously injure the rail and result in easy failure under shock.

4. As a general conclusion these tests show that autogenous welding and cutting of rails produces severe internal strains that frequently reduce the strength under tension shock more than 90 per cent. Unless the welded portions are not subject to reversal of stresses or are sufficiently reinforced by adjoining members,

such as angle bars, autogenous welding or cutting of rails for main line service must be considered a dangerous practice. It is understood that there was no annealing after the welding just as would be the case of welding a rail in the field, or plant without an annealing furnace, as under track conditions.

Tire Welding and Cutting

About this same time there developed an excessive number of tire failures, especially of locomotive driver tires and analysis of conditions showed that worn flanges had been built up by autogenous welding or that the retaining lip had been cut off with a gas flame leaving a series of small nicks that localized the strains and served as a starting point of the tire failure. Twenty-five per cent in one year of our post war tire failures resulted from questionable practices that crept in during the war time. With these conditions present an investigation was made to determine the effect on the strength of the material produced by local heating when building up worn tire flanges by either the gas or electric process of welding and also the effect of the gas cut edge. The tires were cut off or broken into convenient lengths and put under the drop test to determine the resistance to shock. Analysis of the data leads to the conclusions that gas cutting of the edge and both gas and electric welding process as applied to tire steel, set up strains in the metal which lowered the resistance of this class of material to shock about 50 per cent and contributed to failure of the tires both during application to wheel centers and in actual service.

Equipment

With an extensive use of oxy-acetylene it is only natural that various manufacturers of equipment should produce torches and regulators that have real merit and from time to time the test department is called on to make comparative tests as to performance. A series of such tests were started in 1921 on two outfits—A and B, which were used alternately, first A one month, then B the next month, the operator each time being supplied with the same set of equipment and record kept of any difficulties encountered. This gave results under as nearly identical service conditions as possible. These observations were supplemented by tests showing gas and oxygen consumption under similar service, doing the same amount of work or working the same length of time with each outfit. The analysis of results showed the continuity of operation as affected by the back fire in favor of A, that both outfits were subject to service disorder, outfit A showing slightly better in this and also using less oxygen and acetylene per square inch of metal cut, but A requiring a longer time per unit cut than outfit B under the same conditions. Investigations have also been conducted of the merits of various electric welding machines to

secure the one that is best for service. Regular control is also exercised for welding rod to see that it flows properly for the work intended. This is usually handled by the welding foreman so that proper wire will be used.

Locomotive Frame Welding

Another extensive investigation was made a couple of years ago to determine the relative strength and cost of welding locomotive frame bars by the Thermit and electric welding processes. As in many other tests the difficulty is not so much in making the weld as to get material of uniform strength to use as a basis of comparison. Two cast steel bars 4 x 4 in. by 12 ft. long; annealed and made to meet the specification for locomotive frame steel of 80,000 lb. per square inch ultimate strength were secured and six drop test specimens prepared, each 4 ft. long. The drop test with specimens loaded transversely using a 2000-lb. tup with 36 in. anvil spacing was decided on to produce combined shock and tension loads, which would not result by slow transverse loading nor by simple tension loading.

After breaking the six bars, some by alternate bending, others by striking on one side only, they were prepared for the Thermit and for electric welding tests. For the Thermit tests they were sawed square and set up with a proper opening between ends and for the electric weld tests they were sawed at an angle of 45 deg. on two opposite sides, the center line touching, and this "V" opening was then built up with the electric arc using standard No. 6 welding electrode. There was a wide variation of results with the consistency of values for ultimate strength and ductility slightly in favor of the Thermit weld and the relation of elastic limit to ultimate strength costs and time of application in favor of the electric welds. In explanation of this, it might be of interest to point out that frame welds may be of bars 2 x 2 in. or 4 sq. in. area; or 7 x 8 or 56 sq. in. or larger in area. The location may be such that for Thermit welding a lot of work in removing parts is necessary to place molds, cupola, shield, preheating torch, etc., and to make allowance for shrinkage which may not be necessary with electric welding. Because less allowance for shrinkage is necessary, less room is usually required to perform the electric welding operation, and time and cost figures are in favor of the electric weld. In these tests the specimens were all saw cut, while under the locomotive it would undoubtedly be more economical to make gas cuts and chip the surface to remove the metal in preparation for the welding.

Welding Crossings Rails

One problem leads to another. Our maintenance of way department was experiencing considerable difficulty in keeping up the rail joints in road crossings and had experimented some by welding these rails and omitting the joint bars. Service records showed

both good and bad results so requests were made as to possibilities and a series of tests were made to determine the strength of joint obtainable by oxy-acetylene welding rails as in track, top and sides only, and as out of track where the base can be reinforced, and also the effect of using different kinds and combinations of welding material.

Three grades of steel were obtained from one distributor, which we will call No. 1, No. 2 and No. 3. These showed an analysis as follows:

Sample	Carbon Per Cent	Manganese Per Cent	Phosphorus Per Cent	Sulphur Per Cent	Silicon Per Cent	Nickel Per Cent	Chromium Per Cent
No. 1	0.27	0.32	0.014	0.050	0.09	...	...
No. 2	0.91	0.47	0.015	0.035	0.14	...	...
No. 3	0.40	0.70	0.026	0.020	0.61	0.90	0.22

The welding was done by an experienced welder and the rails thus welded were loaded transversely in a 200,000 lb. testing machine with 36-in. span and if not broken they were placed under drop tests, starting with a 1-ft. drop and increasing by 1-ft. increments until failure resulted. The resulting micro-structure was also studied and showed interesting variations in the structure, the bonding area between the filler or welding material and the stock showing very plainly. The conclusions reached were stated as follows:

1. The No. 3 steel produces a stronger, sounder and harder weld than the No. 2 steel and also stronger than No. 1 working under the same conditions.

2. Welding as out of track, that is, turning the rail, resulted in a slightly stronger weld on the average, than by not turning it to reinforce the under surface of the base.

3. The welded joint is generally much stiffer than the standard bolted joint and shows a yield point almost as high as the rail, but the ductility and consequent resistance to shock is much lower than that of the bolted joint or of the rail.

4. The rigidity of the welded joint would reduce the joint maintenance costs, but where the rail is subject to severe shocks from high speed trains there is danger of failure due to the low ductility of the metal. This would limit the use of the unbolted welded joint as tested to slow speed track or to such places as crossing pavements which would keep the rails in alignment in case of failure. Welding was recommended for crossings where the outside of rail is supported by the pavement and the inside by the rail or bar used as a flange spacer in the pavement.

Cutting Tests

Some investigations have also been made of the structure of the metal adjacent to the surface as left by the cutting torch

which show a transformation of structure close to the highly heated edge which requires a liberal allowance of metal for machining to eliminate possibility of surface checks. In view of safety, our specifications call for ¾ in. of metal to be left for machining between the finished surface and the cut where a gas torch is used in removing risers, gates or tie bars from locomotive frames. Such gas cutting operations shall be performed before annealing the castings.

Welding Side Frames and Couplers

The frequent occurrence of small cracks in car frames and couplers which resulted in scrapping these castings for what seemed minor defects, prompted a rather extensive investigation last year to determine if gas or electric welded side frames or couplers would fail in welds, or due to welding, and to what extent, if any, such castings were weakened by the use of autogenous welding as a means of reclamation.

Side frames from 80,000-lb. capacity cars were repaired, by both gas and electric welding processes, selecting pieces with comparable defects in each case. Some were annealed after welding and others tested just as welded. The frames were placed in the 200,000-lb. testing machine, supported as in service and loaded to the capacity of the machine and then tested to destruction under the drop test. Couplers were welded and tested under jerk and bending tests to determine the strength, using both annealed and unannealed samples. Twelve side frames and twenty-one couplers were tested to destruction and showed the following results:

1. The failure of side frames did not occur until after the elastic limit of the material had been passed.

2. Welded couplers, as a rule, met specifications for new material except where the failure was of a serious nature such as a broken eye, which indicates that there are limits to which the process can be applied.

3. Proper annealing relieved the welding strains and improved the structure of the material.

4. Gas or electric welding of side frames and couplers with subsequent annealing, can be done with satisfactory results, where original stock is sound.

As a result of the favorable showing of the welded frames tested, more extensive repairs were made by welding such frames during 1924, and the results are shown in Table III, compiled from the standard forms for this class of failures and repairs as kept by the supervisor of welding equipment. This shows the number of castings welded on the system and also the number of welded castings removed on account of failure during the years 1923 and 1924.

TABLE III

	1923			1924		
	Welded. A. T. & S. F.	Failed. A. T. & S. F.	Others*	Welded. A. T. & S. F.	Failed. A. T. & S. F.	Others*
Truck frames	623	5	18	871	7	26
†Truck bolsters	674	5	8	2,771	5	26
Body bolsters	226	0	2	218	1	0
†Side frames	517	10	31	1,884	5	51
Total castings	2,040	20	59	5,744	18	101
‡In service, per cent	96.1	..	..	97.9	..	..
‡Out of service, per cent	..	1.0	2.9	..	0.3	1.8

*Of the failed casting 85 per cent had no marks or were marked as welded on other railroads.

†Approximately 60 per cent of the truck bolsters were built up on account of being worn, and 40 per cent of the truck side frames were welded for the same reasons.

‡The percentage of welds in service and out of service is based on the number of welds made during that year and not on the total number of welds in service at that time.

Summary

The subject of this paper, as you will read, is fusion welding and cutting as practiced on the A. T. & S. F. Railway, and some of you may ask why the test data have been included. Many of the rules, precautions, and "Don'ts" are well known to all of you, but the effects of unknown and uncontrolled heat on iron and steel are an unknown quantity to most of us. It often leads to faulty conclusions, for quite often a man points with pride to the fact that the weld he made is stronger than the stock, and he overlooks the fact that the welding heat which he applied to the stock so transformed the adjoining metal that such a failure was inevitable in the stock. This applies to welding of steels of above 0.30 per cent carbon and danger increases, with increase of carbon content. In this connection an interesting condition was found in the locomotive frame bar welding tests, where the failures usually occurred at the edge of the liberally reinforced Thermit or electric welds. To overcome this condition the welds were extended and contracted in a "V" shape on the four sides to the center of the bar, thus leaving the edges of the bar in line with the extreme edge of the weld in a normal condition. This produced a stronger welded specimen and failure occurred in sound stock, or through the weld if that was not too highly reinforced.

From the presentation of data covering investigation of autogenous welding and cutting, you may realize that it is the conscientious effort on the part of the Santa Fé Railway management to render the best service possible and in order to do this every effort is made to determine the best, the safest and the most economical method of doing this. It is with this end in view that the various investigations have been made and are now under way so that we may know to what extent we can employ autogenous welding and cutting in our work with safety and economy.

The Inspection of Welds in Pressure Vessels*

S. W. MILLER†

Inspection may well be defined as viewing closely, strictly, critically. Its object is to find facts.

In the case of welded pressure vessels, we want to know what they will safely stand in service; maybe pressure, maybe temperature, or maybe a combination of both, so we should inspect with these objects in view. The question of temperature resistance is very complicated, and not thoroughly worked out yet, so we will here speak only of inspection as applied to pressure.

Let us consider first that we must in any inspection make more than a mere visual examination. I cannot recall any instance in which visual examination alone is the decisive factor. We buy a pair of shoes largely on their appearance, but we sometimes find that we do not get good service from them. If we knew more about leather, about its action under bending, about its feel to the touch, how it was manufactured and the reputation and standing of the maker, we would be able to buy our shoes more intelligently, and would be almost certain of getting good service from them.

There has been a tendency for both the maker and user of welded pressure vessels, to feel that fusion welding is a mysterious, rather unreliable process, incapable of being applied by any one but a so called expert, and even then with only a fair chance of success. Whatever the reason for this impression, it is entirely wrong. When we look over the work that is being done, recall the many applications in all branches of industry, and consider how handicapped we would be without it, we are forced to believe that it is as easily learned as any other trade and that its results are just as good.

One of the stock objections to welded pressure vessels is that the welds cannot be inspected as well as other joints, the comparison being usually made with riveting. It is often claimed that a riveted joint can be thoroughly inspected, but no one can tell the condition of many important parts of a riveted joint after it is made, as can be easily seen after a moment's thought. Do the rivets fill the holes? Have the holes been punched full size, or have they been punched small and reamed when the seams are bolted up, as good practice requires? Are there any hidden lap seam cracks, the bane of the boiler inspector? Have the sheets been separated after reaming the holes in line, to clean out chips and remove the burrs? The safety of a riveted tank or boiler depends on the good condition of these items, and yet not one of them can be inspected in any way after the vessel has been made, though they can all be inspected thoroughly while construction is taking

*Presented at the annual meeting of the American Welding Society, April, 1925.
†Union Carbide and Carbon Research Laboratories.

place, and such inspection is customary in the case of boilers and called for in the pressure vessel code.

I would say a little more about lap seam cracks, which often develop in lap riveted joints after a period of service. In many cases they begin between the rivet holes, where the sheets lap and gradually extend toward the outside, so that such a seam may have almost no strength. It is universally admitted that there is no way to detect this defect and many fatal accidents have occurred because of it.

So we find that there is small basis for the claim that riveted joints can be thoroughly inspected.

It is customary and proper to inspect riveted construction and it is equally proper to inspect welded tanks and for the protection of the industry, we should insist on it just as we insist on bonding our treasurers. It is good business.

The inspection must cover

1. Design.
2. Material.
3. Workmanship.

Proper design is necessary, not only for strength, but to insure good workmanship. It is not fair to expect any welder, no matter how competent he may be, to weld securely and safely a poorly designed tank. The essential feature of good design is the 90 deg. V, with both angles of the abutting plates equal, as in Fig. 1. For heavy plates, say ¾ in. thick or more, there is some advantage in opening the V somewhat more, as in Fig. 2. Fig. 3 shows the usual head or girth seams, while Fig. 4 is more economical and easier to weld in heavy plate, especially when the head is thicker than the shell.

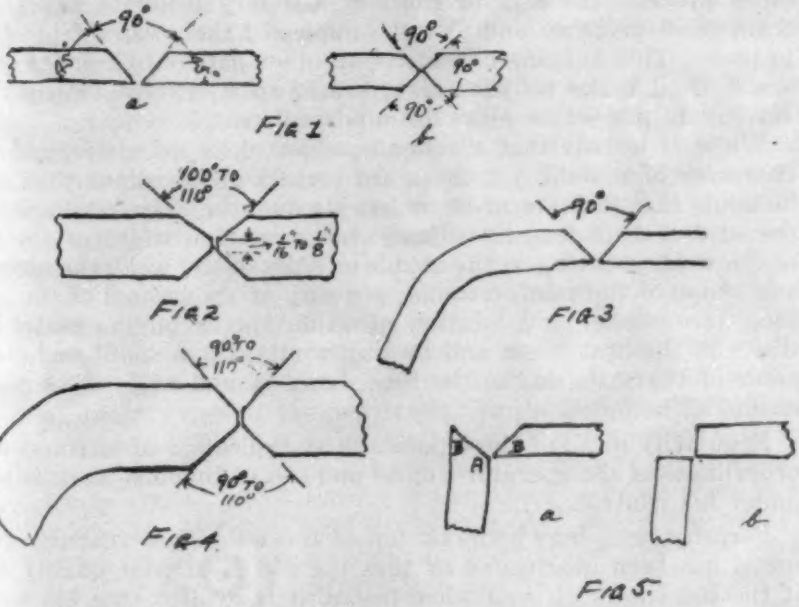
The design in Fig. 5-a should not be used as the welder cannot easily bring the two unequal angles, A, to the welding heat at the same time, and as the angle B burns off readily, thus tending to prevent good fusion and penetration. Fig. 5-b is all right. However, in both these designs stays must be placed close to the welds to prevent breathing stresses breaking them, and neither should be used in pressure vessels unless absolutely necessary.

The next feature of design is the allowable working fiber stress. This is quite fully covered in our Bulletin No. 5, the recommendation being 8000 lb. per square inch, and reference should be made to the bulletin for details. The stress allowed may be set by law, in which case it will have to be followed.

Then come the pipe connections. Good designs are shown in the A. S. M. E. Pressure Vessel Code, which are based on the recommendations in Bulletin No. 5, which specifies, more clearly than does the code, the conditions under which the different designs should be used, particularly with regard to pressure and tank diameter.

The materials, that is, the plate and welding rod, should be

bought under specifications, and must be inspected to see that they comply with the requirements of these specifications. Bulletin No. 5 and the Pressure Vessel Code give the essential points, especially the former. The most important matters are that the plate should be of low carbon content, of low tensile strength, and of high quality, firebox plate being the best, because such material stands heating and cold working with little injury. The welding rod is easily tested for welding quality by melting it with a small flame and observing its action. If this action is good and



it meets the specifications of the A. W. S. in Bulletin No. 2, it may be relied on.

Workmanship includes the methods employed as well as the actual welding. Methods differ in different shops, but these differences are of no importance, provided the desired result is attained. For example, one shop may use jigs and another may hold the work by tack welding, but if the tank is round and symmetrical when finished, nothing more can be asked. It is important that the procedure be properly controlled; that is, a proper procedure must be developed and followed strictly. Inspection is necessary to this end.

An inspector must know when good welding is being done, just as he must know when good riveting is being done, because in neither case can the eye determine the conditions inside the joint. This means that the inspector of welded tanks should be trained in welding, just as his associate in riveted work is trained in rivet-

ing. This training is not difficult to acquire, and does not take unduly long, the essential points being that he must recognize thorough fusion and penetration when he sees it and be sure that the flame is neutral.

It is no more possible for a welding inspector to observe each inch of welding done than it is for a riveting inspector to see each rivet driven, but in either case, he can be sure enough of the quality of the work to pass it if what he sees done is acceptable.

Good operators are, of course, essential if good welding is expected. This is no more true of welding, however, than of any other process, the only precaution necessary being to select and train them properly and to test samples of their work from time to time. This is being considered in other papers to be presented, and I shall make no further reference to it, except to say that here again inspection plays an important part.

While it is true that visual inspection does not determine the character of a weld, yet there are certain observations that may be made that indicate more or less its quality. The regularity of the surface both lengthwise and cross-wise, the width of the top of the weld, grooving at the center or sides of the weld, the amount and shape of the reinforcement, porosity or sponginess of the surface, the number and location of oxide specks on the plate, the width of the heat effect and its uniformity, the amount and character of the scale due to the heat, both on and next to the weld, should all be noted.

Regularity in all of these points is an indication of neatness and orderliness of the operator's mind and shows that his work is well under his control.

Porosity or spongy spots on top of the weld show that the weld metal has been overheated or that the rod is of poor quality and if the rod shows up well when tested, it is evident that too hot a flame has been used, or that it was not neutral; an excess oxygen flame will burn any welding rod, and an excess acetylene flame is nearly as bad, for it adds carbon to the weld metal, tending to make it brittle.

The width of the top of a single 90 deg. V before welding is twice the thickness of the plate when the bottom edges are together and with a double V equals the thickness of the plate. Evidently if the width of the top of the weld is less than this, the V angle has been too small, and if very much more, the V has been too wide, or more probably, the welder has gone over his work too much, tending toward a dirty weld and overheated plate. If the width at the top of the weld is about two and one-half times the depth of the V, it is an indication of good work.

Many round specks of oxide, especially if they are far from the weld, indicate either poor welding rod or excessive size of flame, the latter being probable, especially if the welding rod has been tested and found good.

The coloring of the plate by the heat should extend uniformly parallel with the weld and at a distance from it depending on the plate thickness. If too close, the weld is probably poorly fused to the plate and the full thickness is not welded. Too great width shows that an unnecessary amount of heat has been applied, while irregular width indicates irregular quality. In a single V 90 deg. weld in ½-in. plate, the heat effect should be about 3 in. wide. The surface of the plate has something to do with this width for if it is heavily scaled the color change may be masked.

A large amount of scale on or near the weld indicates excessive heat or poor flame regulation. There will always be a thin film of oxide on and near the weld, but an excessive amount should excite suspicion.

Grooving at the sides of the weld may be due to poor quality plate, but probably is caused by the carelessness of the operator, as he can always fill up holes if he tries to. Grooves or low spots in the weld are sure evidences of poor welding, while if the amount of reinforcement is as specified by good design, and it is regular both lengthwise and crosswise, good work is indicated.

The bottom of a single V weld should always be examined. If the weld is well made, there will be a rather uniform bead of metal extending slightly through the V. This should not be confused with melted oxide, which can be easily cracked off with a hammer. The hammer and wire brush should always be used in case of doubt, to see if the penetration to the bottom of the V has been complete. With bad penetration it is not necessary to use either, as the bottom edges of the V have not been fused at all, and are clearly visible. This always is suspicious, because there is no telling how far down the weld has been made. But, taken with the other appearances, such as width of the top and the heat effect, a rather fair idea of the penetration can be obtained. It may be fairly said that one of the great advantages of the double V weld is that it eliminates the crack that is often at the bottom of the single V type, which is just as dangerous as any other crack. This advantage is clearly shown in Bulletin No. 5.

It is thus seen that for proper inspection of welded pressure vessels, the examination must begin back of the actual welding, and must include everything that goes into the construction. If this inspection be properly controlled, the results cannot fail to be satisfactory.

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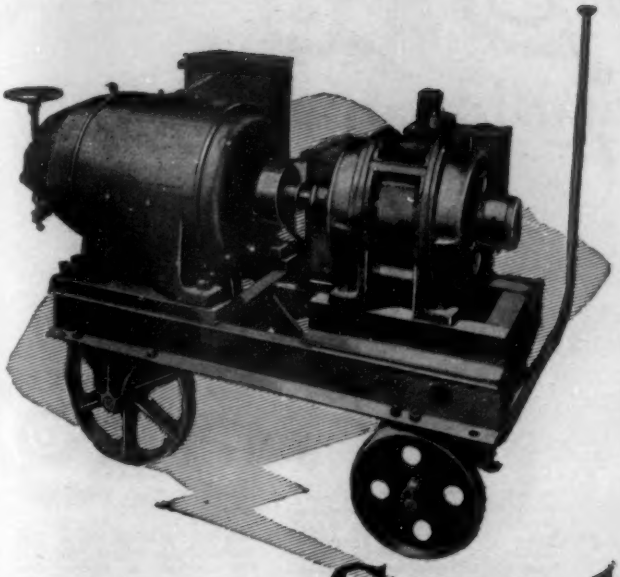

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